AD-A267 098

Semi-Annual Report:

Grant Number: N00014-93-1-0128

A Study of High Field Transport in Wide Band Gap Electronic Materials Using a Picosecond Transient Charge Technique

July 2, 1993

Prepared for: Scientific Officer Code: 1114SS
Max N. Yoder
The Office of Naval Research
Electronics Division
Arlington VA 22217-5000

DTIC
ELECTE
JUL 22 1993
S E D

Prepared by: Craig J. Scott
Dept. of Electrical Engineering
Morgan State University
5200 Perring Parkway
Baltimore MD 21239
(410) 398-3298

E-Mail: cjscott@moeng2.morgan.edu

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

93 7 20 054

93-16434

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
July 2,1993

3. REPORT TYPE AND DATES COVERED
Semi-Annual Nov.30 -July 2

4. TITLE AND SUBTITLE
A Study of High Field Transport in Wide Band Gap Electronic Materials Using a Picosecond Transient Charge Technique

5. FUNDING NUMBERS
G1114 SS
R&T PROJECT 4145398--01
PE 61153N

6. AUTHOR(S)
Craig J. Scott

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
MORGAN STATE UNIVERSITY
COLDSPRING LANE HILLEN ROAD
BALTIMORE, MD 21239

8. PERFORMING ORGANIZATION REPORT NUMBER
1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
OFFICE OF NAVAL RESEARCH
CODE 1511;MMW
BALLSTON TOWER ONE
800 NORTH QUINCY STREET
ARLINGTON VA 22217-5660

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
NONE

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approve for public release
Distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

We propose a study of electron and hole traps and carrier drift velocity for high electric field strengths using the transient charge technique (TCT) with a picosecond electron beam probe. The uniqueness in the proposed approach lies in the use of a photocathode SEM to generate picosecond electron pulses with high lateral resolution to generate electron hole pairs. Ultrafast electron beam pulses allow narrow drift regions to be characterized and allow high field measurements to be performed without thermal heating.

14. SUBJECT TERMS
Diamond, velocity,time of flight, and picosecond

15. NUMBER OF PAGES
9

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
17 unclassified	unclassified	unclassified	UL

Table of Contents

Accesion For		
NTIS CRA&I	X	
DTIC TAB	☐	
Unannounced	☐	
Justification		
By		
Distribution /		
Availability Codes		
Dist	Avail and / or Special	
A-1		

A Study of High Field Transport in Wide Band Gap Electronic Materials Using a Picosecond Transient Charge Technique

Program Overview

Wide Bandgap materials such as SiC and Diamond have been the subject of considerable research interest. The high temperature, high frequency, high power, and radiation tolerant properties suggest these wide-bandgap semiconductor materials have tremendous potential for military applications. High frequency bipolar transistors and field effect transistors, thermistors, IMPATT diodes, and short wavelength optical devices have been proposed using these materials. Although research efforts involving study of high field transport in SiC and Diamond have made significant advances, much work is still needed to improve the material quality so that the electrophysical behavior of device structures can be further understood and exploited. Carrier transport measurements serve to verify theoretical calculations and device predictions. In this work we propose a study of electron and hole traps and carrier drift velocities for high electric field strengths using the transient charge technique (TCT) with a picosecond electron beam probe. The uniqueness in the proposed approach lies in the use of a photocathode SEM to generate picosecond electron pulses with high lateral resolution to generate electron hole pairs. Ultrafast electron beam pulses allow narrow drift regions to be characterized and allow high field measurements to be performed without thermal heating.

Objectives

In this program the Department of Electrical Engineering at Morgan State University (MSU) will perform a three year research effort with emphasis on the characterization of SiC, Diamond, as well as other wide bandgap electronic materials using a picosecond transient charge technique (PTCT). As we envision our effort, this will be carried out by: 1) implementing the setup of a photocathode SEM. 2) Fabricating high field carrier transport test structures. 3) Performing drift velocity and carrier trapping measurements. 4) Characterizing high frequency devices with large signal measurements.

Progress To Date

To achieve the goals stated earlier, the picosecond photocathode SEM electron beam test method will be used to perform transient charge measurements. The implementation of the electron beam tester is the most demanding task of the proposed effort. A diagram of the experimental setup for the measurement system is shown in figure 1. An existing Hitachi S-520 SEM has been retrofitted with a photocathode electron gun and 26.5 GHz electrical SMA feed throughs. In the original technical approach an ISI Super IIIA SEM was to be modified. The Hitachi SEM was donated by The ATL Division of Westinghouse Electric Corp. This SEM has an existing turbopumped vacuum system. By taking this approach, resources could be applied to automating the tester one year ahead of schedule.

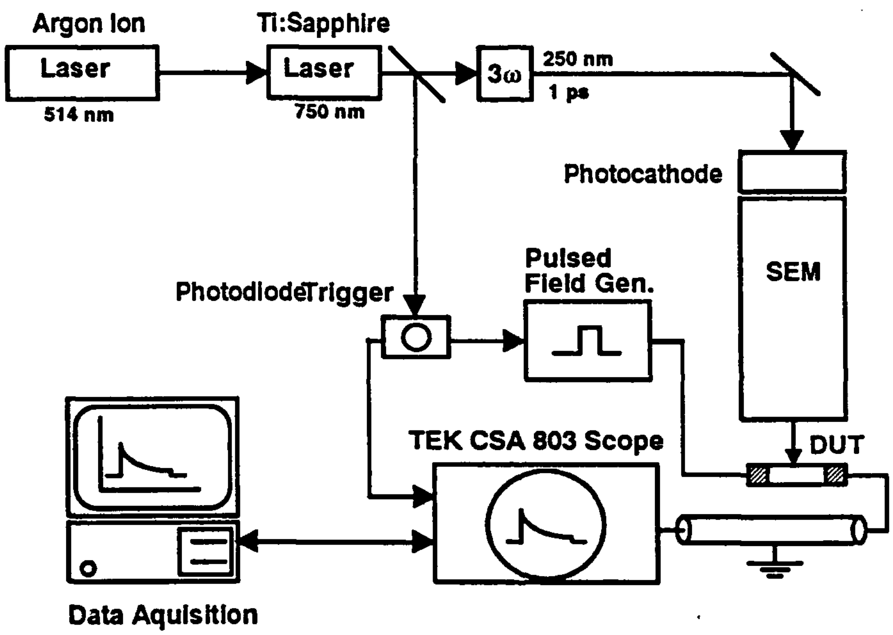

Figure 1. Experimental setup for the picosecond photocathode tester.

Facilities requirements for the SEM, electron beam evaporator and the laser have been meet and all major equipment items are operational. The laboratory is situated in a new building. All the facilities requirements had to be added as renovations that were accomplished with funds provided by the University. Thin 180Å gold layers on UV grade quartz substrates have been fabricated. The current voltage characteristics of the cathode will be measured as soon as frequency tripling of the Ti: sapphire mode locked laser is accomplished. The manufacturer of the phase matching portion of the frequency tripling assembly shipped the wrong unit. The problem has been identified and the correct part will be sent. A fundamental wavelength of 750 nm from the Ti: sapphire laser will be used, subsequently tripled (λ divided by three) to 250 nm and used to excite the electrons at the photocathode. Operating at a shorter wavelength will result in a brighter cathode source. Until now most picosecond pulsed UV sources used frequency quadrupled modelocked Nd:YAG lasers operating at 266 nm. Autocorrelation measurements indicate the pulse width at 750 nm is 2.0 ps.

A separate high vacuum chamber for photocathode testing is being setup. It is an ion pumped Perkin Elmer analytical chamber with multiple 4" and 2.75" ports. This chamber was provided by the Army Night Vision Laboratory in Ft. Belvior VA. By making contact with various material growers nationwide we are in the position to test various cold cathode and photocathode layers for possible use in this instrument.

A Tektronix CSA 803 50 GHz oscilloscope is used to record the current transient from the sample. The oscilloscope has been purchased and we are writing the software for a PC to capture the current pulses and analyze the pulsewidths. We will also use the TDR feature of this scope to characterize the measurement test fixture and high frequency electrical connections The 26.5 GHz connectors will limit the minimum pulse to 26 ps or a minimum transient width of 2.6 microns.

Two sample geometries have been investigated for use in the measurements. The lateral and vertical geometries are shown in figure 2. The lateral configuration lends itself well to high frequency fixturing and can be integrated into a microstrip waveguide. The vertical geometry cannot be used in the microstrip configuration. This geometry will be used during the initial testing phase. A photomask for patterning gold and aluminum microstrip traces on the alumina substrates has been designed. Gaps of 0 µm, 250 µm, 500 µm and 1000 mm are centered in a 50 Ω transmission line. The substrate holder is 2" X 2" and has SMA coaxial to microstrip launchers. Fabrication of the microstip lines at Morgan is currently underway.

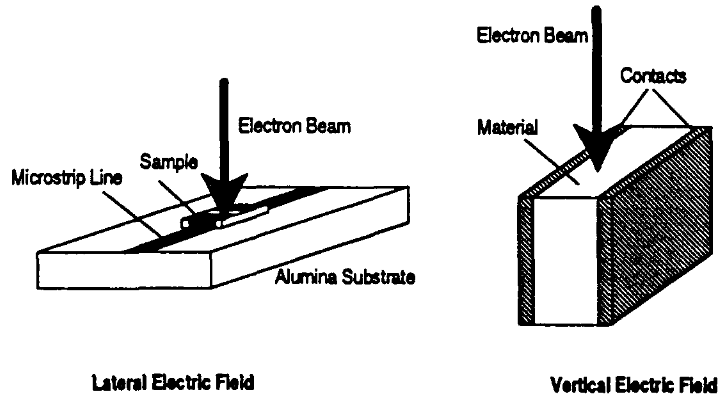

Figure 2. Lateral and Vertical sample test geometries.

Photocurrents from electron irradiation were calculated as a function of the primary electron current and energy for diamond, SiC, AlN, and GaN substrates. (Figure 3.)

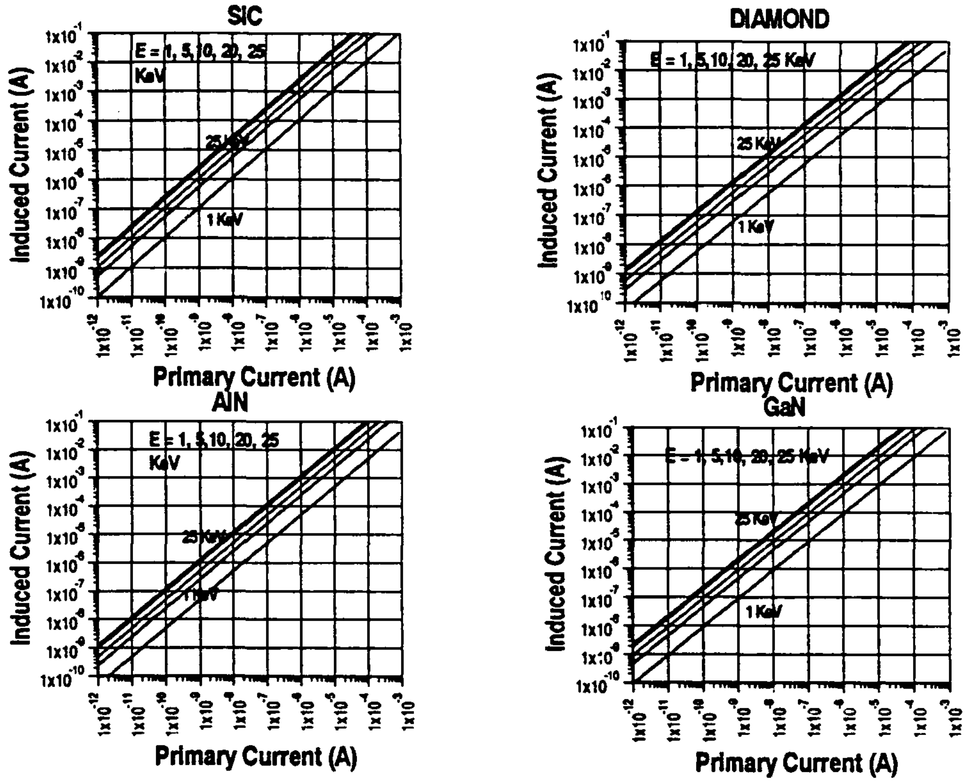

Figure 3. Photocurrents for various wide-bandgap materials.

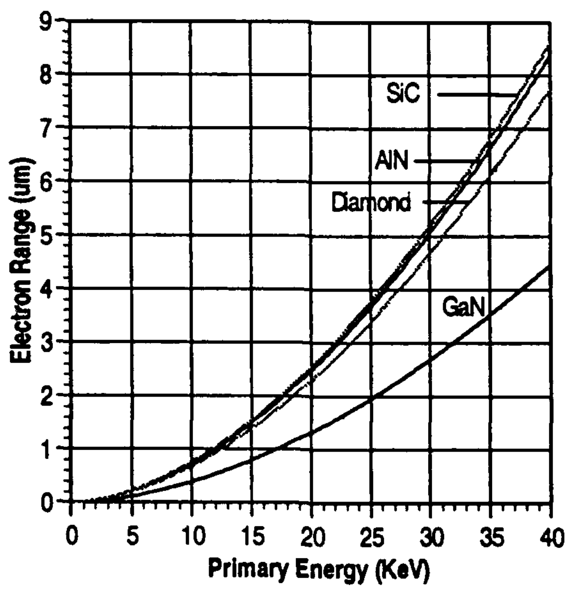

Figure 4. Primary beam range for various wide-bandgap materials.

Shown in figure 4. is the calculated electron range as a function of energy in the various substrates. With a 20 KV high voltage source, electron penetration depths of over 2 μm can be achieved. These calculations indicate the minimum thickness and anticipated signal level for the various materials in our tester.

Samples have been received from Raytheon, Norton SI, Howard and Johns Hopkins. The Hopkins sample is GaN. The Howard samples are AlN on sapphire. Penn State, North Carolina State, and LMA associates have agreed to supply samples when the tester is fully operational. Bob Davis from NCSU also would like to have some AlN and GaN samples characterized.

A program Gannett chart is shown in figure 5. The procurement and facilities tasks have been completed according to the proposed first year plan in the statement of work in the original proposal. We are now implementing the setup of the photocathode SEM. The first PCTCT measurements should be possible by August, four months ahead of the original time schedule.

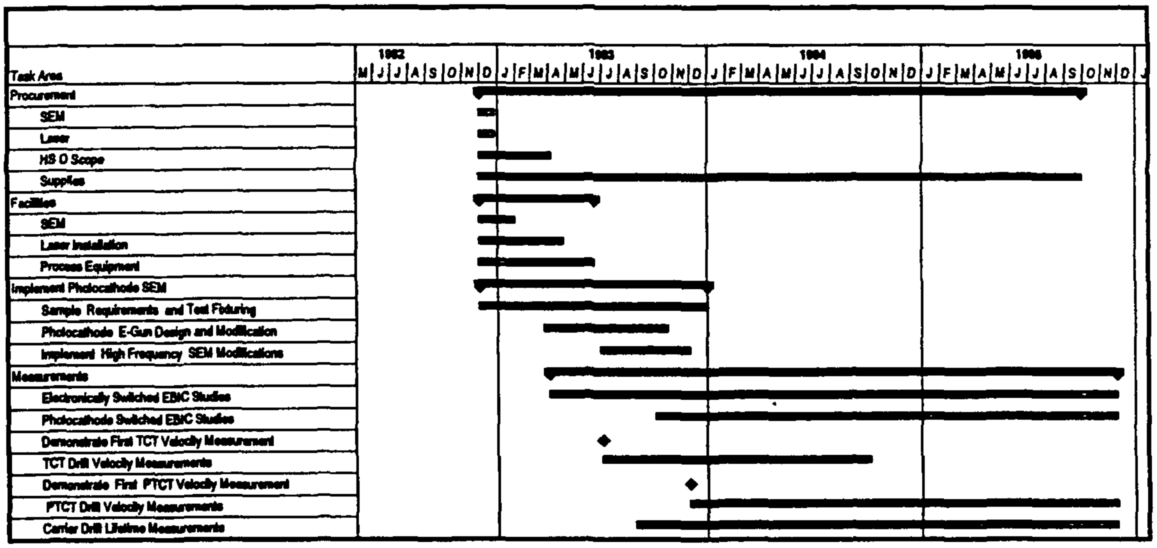

Figure 5. Program timetable.

At present, three graduate students, two from Johns Hopkins and one from Virginia Polytechnic, and are working on this program over the summer. Arrangements for two of the graduate students are being made so that they may perform their research at this laboratory. Five undergraduate students are summer interns of which three will continue research during the academic year. This program is an excellent vehicle for undergraduate research experience.

Summary

The program is proceeding on schedule and in some cases ahead of schedule. We are nearing completion of the photcathode tester design and implementation phase. A proof of concept demostration of a velocity feild measurement will be performed by the end of this summer. From here we will continue to refine the experiment and investigate the temporal and spatial attributes of carrier trapping in diamond and related materials. There are no major technical hurdles to overcome to demostrate the proposed test capability.